Making Connections

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Sponsored by the Photovoltaic Systems Assistance Center, Sandia National Laboratories

PV systems often use components that cannot be easily connected to other equipment. Making electrical connections that meet code requirements can be problematic if the installer is not experienced. This column will look at some of the techniques, hardware, and components used to make electrical connections in a PV system.

Twist-On Wire Connectors—Bad Rap from the Past

Many PV installers think (and are being taught) that twist-on wire connectors (aka Wire Nuts) are not suitable for use in the DC circuits of PV systems. This information is derived from the early, improper use of twist-on wire connectors in PV systems. Before about ten years ago, twist-on wire connectors were listed only for use in dry, interior locations. Early PV installations saw them installed in outdoor junction boxes that were sometimes filled with water. Some connectors were installed in exposed outdoor locations to connect module wires together. Both of these types of installations resulted in early failure of the connectors and in a very bad reputation that has persisted until present times.

Twist-on wire connectors, now made by several manufacturers, are listed and fully suitable for use in dry locations, damp locations, wet locations (indoor and outdoor), or direct burial service. As with any other piece of electrical equipment, the installer must read and heed the instructions for each type of connector. These instructions will generally include the following:

- Service location—dry, damp, wet, or underground
- Temperature rating—75°C, 90°C, or 105°C
- Voltage rating—may vary with application (fixture or nonfixture)
- Conductor stripping length
- Combinations and size of conductors that can be inserted
- Insertion of solid or stranded conductor first
- Pretwisting conductors
- Twisting insulation so many turns outside the connector or not
- Other limitations such as once-only use, or not suitable for aluminum conductors

Implied in these instructions and also in the *NEC* , these twist-on wire connectors provide only the electrical connection and the insulation for that connection. They do not provide the splice with the mechanical strength of the

Twist-on wire connectors make for code compliant connections if used properly.

Use specialty connectors in specialty situations.

unspliced conductor. This indicates that these connectors should be installed in pull or junction boxes where the attached conduit provides the strain relief or where cord grips are used on exposed conductors entering the J-box. Direct burial cables are provided with strain relief by the surrounding soil.

Split Bolts—Heavy Duty Connections

Spilt bolts are available in a number of sizes, from the tiny units used to splice #20 (0.5 mm²) conductors to monster-sized units for 500 kcmil (254 mm²) and larger cables. They clamp the two conductors firmly together, are tightened with a wrench (to the manufacturer's specified torque), and provide both a mechanical and electrical connection. Usually they are designed and listed to splice only two conductors.

Because they are bare metal (copper, tinned copper, or tinned aluminum), they must be insulated, and the insulation must be equal to the insulation on the unspliced conductor. This means that just a couple of layers of 1,500 volt rated, PVC electrical tape may not be sufficient. In many "warm" PV installations, the tape will soften and the sharp points on the split bolt will penetrate the tape with possibly disastrous results. The insulation applied to a split bolt must equal the insulation of the unspliced conductor, plus you must take into account the sharp points on these devices. Several layers of fabric tape and rubber tape can be used to properly insulate and mechanically protect a split-bolt splice. Rigid and flexible plastic covers are available to provide insulation on these devices. The conductors are bolted together with the split bolt, and the cover snaps on to complete the installation.

Various types of split bolts are available and may be used for copper-to-copper, copper-to-aluminum, or aluminum-to-aluminum connections depending on the design and materials. Each device is marked with the allowable conductor types.

Split bolts provide both mechanical and electrical connection, and come in sizes for most gauges of wire.

Double Lugging—A Common Code Violation

For some reason, PV systems designers and the equipment designers often seem to want to make more electrical connections to a single point than there are terminals for that point. The uninformed PV installer may need to connect two conductors to a single point, and the terminal or lug appears to be large enough to hold the two conductors. In they go, they appear to fit, and the terminal bolt or screw seems to tighten properly. (You did use a torque wrench or torque screwdriver, didn't you?) This is called double lugging, and it is a code violation in many cases. If the terminal is listed for use with only a single conductor, it may not be used with more than one conductor, no matter how many will fit.

Most commercial electrical equipment has a sufficient number of terminals for each wiring point, but even in those installations, it is sometimes necessary to connect multiple conductors to a single point. For example, how can we connect two #2/0 (67 mm²) conductors in parallel to the single box lug on a Heinemann 250 amp circuit breaker in a Xantrex DC 250 enclosure? Sure, two #2/0 conductors will fit in the box lug on the circuit breaker that is sized to accept up to a single, 250 kcmil (127 mm²) conductor, but that doesn't make it right or code compliant. Just because Xantrex, in the factory, can remove the box lug, use a longer bolt, and connect a second wire under the box lug on the breaker doesn't mean we can do it in the field. The factory manufactured item has been listed for the second attached wire. How can we meet code and get the job done?

We can do it in several ways. First, if there is room, the two conductors could be connected to an appropriate split bolt where one conductor is terminated and the second conductor continued through the split bolt to the circuit breaker box lug. No ampacity problems should result, because the ampacity of conductors in enclosures is based on the free air ampacity (*NEC* 310.17) and the conductor is bare (uninsulated) for the less than 1/2 inch (13 mm) between the split bolt and the box lug.

A caution is in order with this type of connection. The split bolt, after taping, may contact the front of the enclosure that houses the circuit breaker. If the taped insulation is not adequate, it may wear (or melt) through, causing the conductor to fault to ground through the grounded enclosure. Depending on where the overcurrent device is located with respect to the current sources, this can get pretty exciting as the front panel melts.

NSi Industries, Inc. makes a series of multiple conductor connectors (their Polaris line) that are fully insulated and accept a wide range of conductor sizes. They are ideal for splicing larger conductors together, and the insulation precludes problems even when they touch grounded surfaces. The photo on the next page shows one being used. It parallels two #2/0 conductors, connecting the pair to a 250 amp circuit breaker and also providing a third lead for a feeder to another circuit. A smaller Polaris connector can be used to make the multiple connections required in an inverter bypass switch using a Square D QO load center and

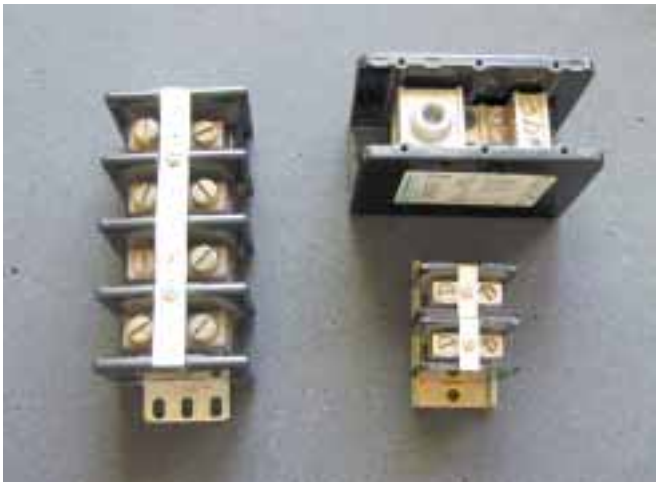
Multiple conductor connectors by NSi Industries provide pre-insulated connection for various sizes of wire.

QO circuit breakers. These connectors are available at many electrical supply houses.

Power Blocks

Power combining and terminal blocks are handy for connecting two or many conductors together. Numerous sizes and configurations are available from various large electrical parts suppliers. Only fully listed products should be used in field installations or in equipment that is not fully listed. Get the specifications before you buy. In the photo below, the two power blocks/terminal strips on the right are only UL "recognized," not fully listed (see sidebar). They are therefore unsuitable for installation in code-compliant PV systems. The terminal block on the left is fully listed. Markings on the device will indicate the listing or recognition category. Beware, many devices purchased through electronics suppliers are neither recognized nor listed.

A UL-listed power block alongside two "recognized" power blocks. The latter are unsuitable as installer supplied components in code compliant RE systems.



UL Recognized

A UL recognized component (signified by a UR symbol that is backwards R) is a component that has been evaluated by UL against a set of specifications established by the *manufacturer.* It has not been fully evaluated against a set of specifications found in a *UL standard.*

The recognized component may be used by an original equipment manufacturer (OEM) inside a product that is further evaluated as an entire product against a UL standard. The evaluation of the entire product results in a listing and the product is said to be UL listed. Other laboratories like ETL and CSA can also list products against UL standards. Only UL has a component recognition program.

Recognized components by themselves can never be assembled in the field during the installation of a code-compliant electrical system. For example, the UL-recognized power blocks shown on the right in the photo below cannot be used by PV installers or homeowners in the assembly of combining boxes. However, Xantrex or Outback may use the same device in the factory assembly of a listed combiner box because that listed box has been fully evaluated for the safe use of that recognized component. Unfortunately, several of the larger PV equipment distributors sell UL recognized components to the uninformed buyer.

UL listed **UL recognized**

Soldering, a Time-Honored Solution

Contrary to common belief, soldering conductor splices is allowed by the *NEC* (see Section 110.14(B)). But note that the two conductors must have an electrically and mechanically secure connection before the splice is soldered. After the soldering, insulation must be added so that the splice is insulated as well as the unspliced conductor.

Soldering is somewhat of a lost art. High levels of heat are needed, along with the use of noncorrosive electrical-grade solder. High-heat soldering guns and irons should be used rather than the low-heat soldering pencils used to solder electronics circuits. Listed, heavy duty, heat shrink tubing with internal meltable sealant installed, with a heat gun, provides sufficient insulation for most installations.

Good Connections

Connections are one of the weak links in the electrical circuit chain. When made properly, using listed equipment and tools and following the requirements of the splicing device manufacturer and the *NEC*, they should last as long as the conductors themselves.

Use an appropriately sized soldering gun (right) to match your job. A heat gun (left) is used to apply heat shrink tubing to the connection.

If you have questions about the *NEC* or the implementation of PV systems that follow the requirements of the *NEC*, feel free to call, fax, e-mail, or write. Visit the SWTDI Web site for more details on PV and the code, and to see all past *Code Corner* columns. Sandia National Laboratories sponsors my activities in this area as a support function to the PV industry. This work was supported by the United States Department of Energy under Contract DE-FC04-00AL66794. Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy.

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The 2002 *NEC* and the *NEC Handbook* are available from the National Fire Protection Association (NFPA), 11 Tracy Dr., Avon, MA 02322 • 800-344-3555 or 508-895-8300 • Fax: 800-593-6372 or 508-895-8301 • custserv@nfpa.org • www.nfpa.org

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